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(56) Documents cited
EP 0492437 A1 EP 0415444 A2

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(54) Optical Isolator

(57) An optical isolator comprises a first polarizer (3) for separating an incident light beam into two light beams which are orthogonal one to another in a direction of polarization and which are non-parallel one with another in a direction of propagation, a 45 degree Faraday rotator (4), a second polarizer (5) which corresponds with the first polarizer (3) in respect of a light beam-separation angle but which differs from the first polarizer (3) by 45 degrees in respect of an angle between the two separated light beams and the polarization of the beams and at least one birefringent crystal plane plate (6) which directs two parallel light beams, in planes of polarization at right angles one with another into a single beam. The first and second polarisers may be Wollaston or Rochon prisms.

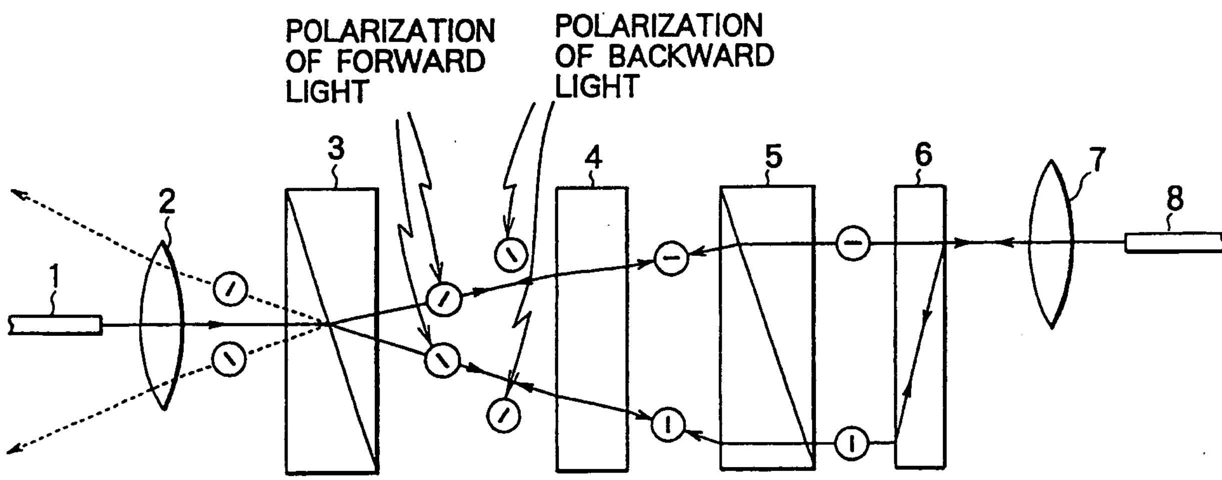

FIG. 1

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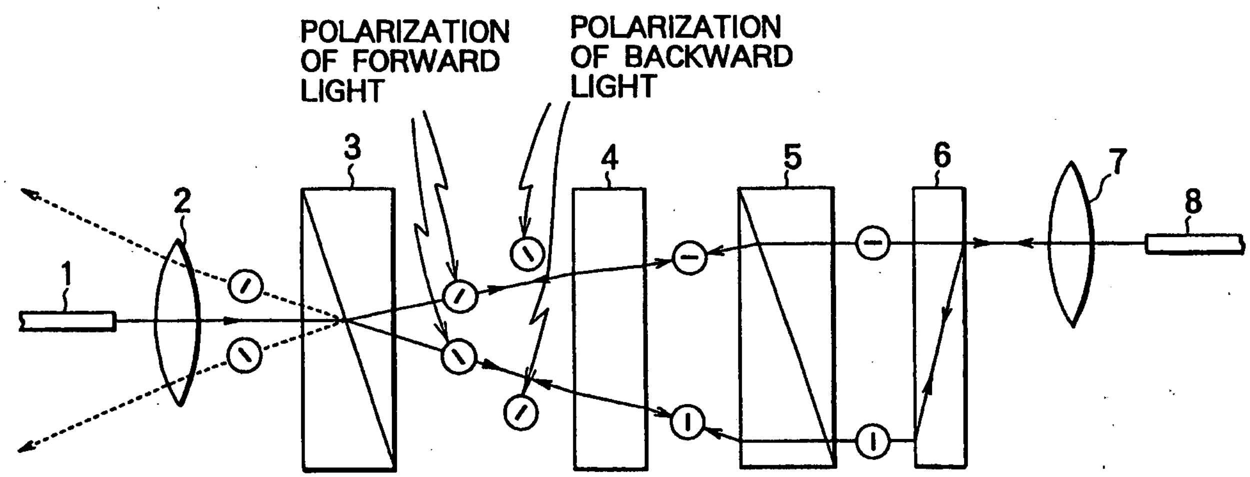
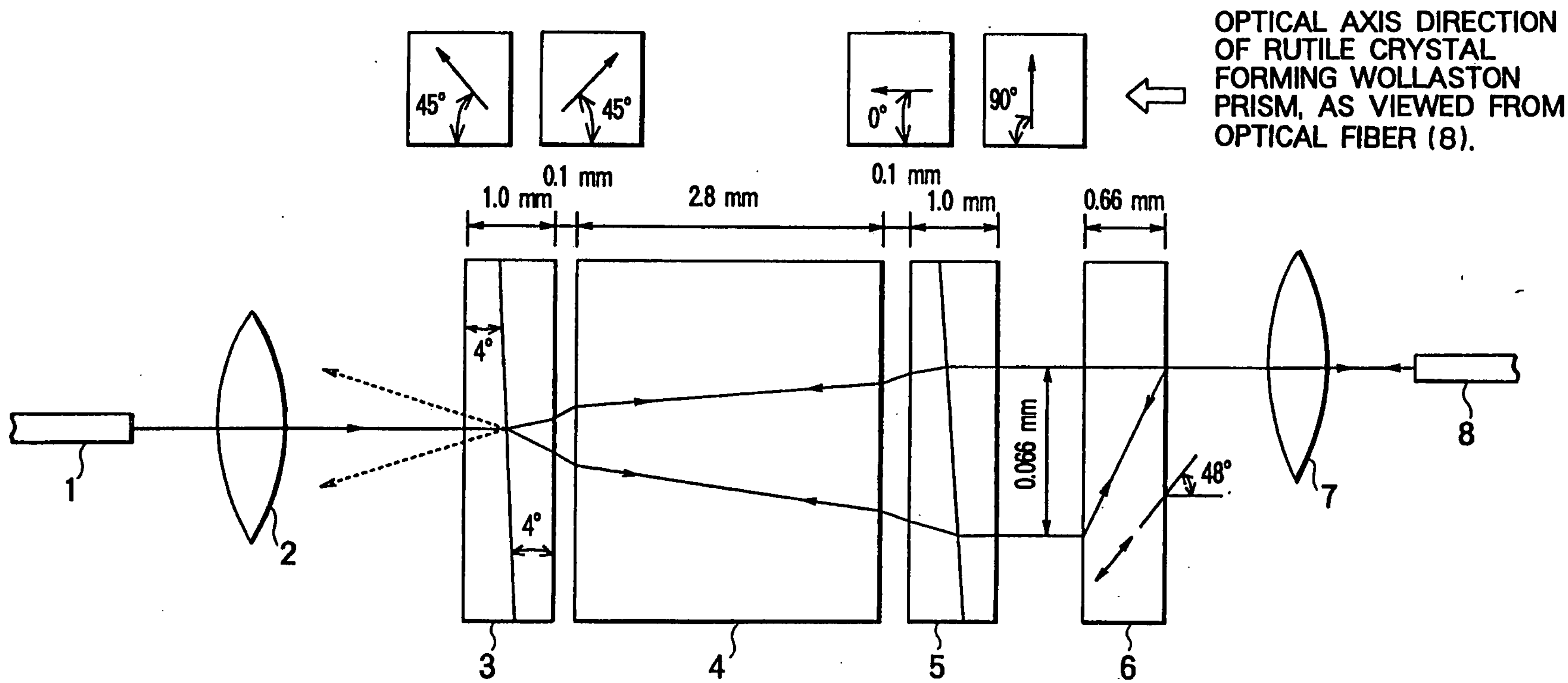
FIG. 1



POLARIZATION OF FORWARD LIGHT
POLARIZATION OF BACKWARD LIGHT
1
2
3
4
5
6
7
8

FIG. 2



OPTICAL AXIS DIRECTION OF RUTILE CRYSTAL FORMING WOLLASTON PRISM, AS VIEWED FROM OPTICAL FIBER (8).
45°
45°
0°
90°
1.0 mm
0.1 mm
2.8 mm
0.1 mm
1.0 mm
0.66 mm
4°
4°
0.066 mm
48°
1
2
3
4
5
6
7
8

Optical Isolator

The present invention relates to a plane-of-polarization independent type of optical isolator that is used for optical communications and photometry.

Optical isolators that are inserted somewhere in an optical fiber and operate on light passing through every plane of polarization are now broken down into two types, one using a birefringent crystal plane plate for a polarizer and the other using a birefringent cystal wedge for the same purpose.

However, a serious problem with the type using a birefringent crystal plane plate is that its thickness must be increased, making an optical device unavoidably large. The reason is that the returning light appears in the form of a light beam parallel with the forward light, and so an interlight beam space must be increased so as to prevent the backward light from coming back to the optical fiber.

The type using a birefringent crystal wedge, on the other hand, presents another serious problem. That is, the backward light appears in the form of a light beam that is at an angle to, rather than parallel with, the forward light, so that the prevention of the returning light can be somehow achieved by making the wedge angle large and thereby allowing the light beam of the returning light to make a large angle to the forward light. However, because the forward light leaves the optical isolator while it is divided into two light beams,

there is needed a special optical system for condensing both of two such light beams one on the optical fiber.

An object of the invention is therefore to provide a plane-of-polarisation independent type of optical isolator that has increased isolation but much reduced light loss due to insertion.

According to the invention, the object mentioned above is achieved, if the backward light becomes a light beam that is at an angle to, rather than parallel with, the forward direction and the forward light becomes a single light beam.

To be more specific, the invention provides an optical isolator made up of a first polarizer for separating an incident light beam into two light beams that are perpendicular to each other in the polarization direction and are not parallel with each other in the propagation direction, a 45 degree Faraday rotator, a second polarizer that is identical with the first polarizer in terms of the light beam-separation angle but is different by 45 degrees from the first polarizer in terms of the angle the separated two light beams make to the polarization of the beams, and at least one birefringent crystal plane plate that has a function capable of converging two parallel light beams, with the planes of polarization at right angles to each other, into a single beam.

Preferably, the invention provides an in-line type of optical

isolator equipment which, in addition to the isolator mentioned just above, includes a lens for guiding the light leaving the optical fiber to an inlet in an optical fiber for photometry.

Preferably, the first and second polarizers are crystal wedges Wollaston or Rochon prisms.

The present invention will now be explained, by way of example but not by way of limitation, with reference to the accompanying drawings, in which:

Figure 1 is an illustrative representation of the construction of the invention, and

Figure 2 is a side view of one specific embodiment of the invention.

Referring now to Fig. 1, the light leaving an optical fiber 1 through its exit is converted by a lens 2 into a light beam that is approximate to a parallel beam, and then enters a first polarizer 3. For this polarizer 3, a Wollaston or Rochon prism built up of two birefringent crystal prism elements may be used.

The light beam, incident on the first polarizer 3, passes through the first polarizer 3, whence it propagates in the form of two light beams that are at an angle to, rather than parallel with, each other. This angle is here called the

separation angle, and is determined by the prism angle of the prism forming the polarizer, the type of crystal and the crystal axes.

The two light beams are respectively polarized, with the planes of polarization being determined depending on the direction of the optic axis of crystals forming the prism.

Upon leaving the first polarizer 3, the light beams pass through a 45 degree Faraday rotator 4 and enter a second polarizer 5.

For the second polarizer 5, a Wollaston or Rochon prism may be used, as in the case of the first polarizer 3. The light beam-separation angle of the second polarizer 5 equals that of the first polarizer 3, but differs by 45 degrees from the first polarizer in the angle that the plane defined by the two light beams makes to the planes of polarization thereof. The light passing through this second polarizer becomes two light beams that are parallel with each other.

In order to reduce light loss by insertion according to the invention, a birefringent crystal plane plate 6 is located in the rear of the second polarizer 5, so that, by passing through this plane plate, the two polarized beams can be converged into a single light beam, which is then guided through a lens 7 to a optical fiber 8. It is here to be noted that it is not always required for this lens 7 to have a function capable of condensing all the light energy of the two

parallel beams into a completely single point.

The optical isolator set up as mentioned above works as follows. As the light leaving the optical fiber 1 is converted by the lens 2 into light beams that are approximate to parallel beams and enters the first polarizer 3, the light leaves the first polarizer 3 in the form of two light beams with the planes of polarization perpendicular to each other. The angle these two beams make to each other, when a Wollaston prism is used, is twice as large as that achieved with a conventional wedge form of birefringent crystal.

Then, the light beams pass through the 45 degree Faraday rotator 4, whereby they are rotated 45 degrees in terms of their planes of polarization.

The second polarizer 5 is made equal to the first polarizer 3 in terms of the polarization-separation angle of the two linear light beams, with the planes of polarization turned 45 degrees. In order to fabricate such a polarizer with the use of a Wollaston prism, for instance, its prism angles are made equal to each other, with the crystal axis of the crystal forming the prism turned 45 degrees with respect to the first polarizer.

The use of the second polarizer 5 of such nature enables the light passing through it to provide two polarized light beams that are parallel with each other.

In order to guide the two beams to a single optical fiber 8, it is preferable that the inter-beam space should be narrowed as much as possible. More preferably, the two beams should be in the form of a single beam. To this end, a birefringent crystal plane plate 6 is used.

In order to make the centers of the two light beams, with the planes of polarization vertical to each other, in agreement with each other, it is desired that they be passed through a birefringent crystal plane plate, i.e., a so-called Savart plate, corresponding to their lengths.

When a plane including two beams is parallel with or vertical to the planes of polarization, it needs to use only one birefringent crystal plane plate. If it is neither parallel with, nor perpendicular to the planes of polarization, it is preferable to use two birefringent crystal plane plates.

The light, which has passed through the birefringent crystal plane (Savart) plate and so again taken on the form of a single beam, is guided through a lens 7 to the optical fiber 8.

It is understood that one of the first and second lenses 2 and 7 may be done without, with the proviso that the other can be used to guide the light leaving the optical fiber 1 to the optical fiber 8.

On the other hand, the backward light leaving the optical

fiber 8 is converted by the birefringent crystal plane plate 6 into two light beams with the planes of polarization perpendicular to each other. Then, they enter the second polarizer 5 making use of a wedge form of birefringent crystal, because Wallaston prisms are used for the first and second polarizers. This in turn enables not only isolation to be much more increased but also the optical fiber to be located much closer to the first polarizer 3, making compactness achievable. In addition, the birefringent crystal plane plate 6 is located in the vicinity of the optical fiber 8 to enable light to be much more condensed on the optical fiber 8, thereby making light loss due to insertion smaller.

While the invention has been described with reference to an example in which Wollaston prisms are used for the first and second polarizers, it is understood that the invention can equally be embodied, even with Rochon prisms.

The invention will now be explained at great length with reference to its more specific embodiment.

The first polarizer 3 used is made up of a rutile Wollaston prism of 1 mm in thickness. The prism angle is 4 degrees. The refractive indices of rutile are 2.451 for No and 2.709 for Ne, as measured at the wavelength of 1.53 μm. The upper block diagram shows the direction of the c axis of the crystal axes. As can be best seen from this diagram, the directions of the c axis of the Wollaston prism are + 45 degrees and - 45 degr s, shown at 9 and 10, as viewed from the light-receiving

side. The 45 degree Faraday rotator 4 used is made up of a substance having a refractive index N of 2.25 and a thickness of 2.8 mm. The first polarizer 3 is spaced 0.1-mm away from the 45 degree Faraday rotator 4, that is then spaced 0.1-mm away from the second polarizer 5. The second polarizer 5 is made up of a rutile Wollaston prism with the prism angle of 4 degrees. As shown at 11 and 12, the directions of the c axis of the Wollaston prism are 0 degree and 90 degrees, respectively.

As light enters the optical isolator of such construction and leaves the second polarizer 5, there appear two light beams that are spaced 0.066-mm away from each other and polarized perpendicular to each other. These two beams pass through the birefringent crystal plane plate 6 of rutile, which they leave in the form of a single beam. This is because the plane plate 6 is located such that the directions of the c axis of rutile is 48 degrees thereto, and has a thickness of 0.660 mm. This single beam can be efficiently condensed through the lens 7 on the optical fiber 8, so that the isolator can have much-more reduced light loss due to insertion.

After the returning light leaves the Faraday rotator 4, the plane of polarization is rotated 90 degrees to the forward light, so that the light, upon leaving the first polarizer 3, can appear in the form of two polarized light beams, rather than a single b am. The angles made between the polarized light beams and the incident light beam are about 20 degrees.

This is aboaut twice as large as that would be obtained by using a wedge form of birefringent crystal as a polarizer, thus enabling the isolation of the optical isolator to be increased. Alternatively, the optical fiber 1 may be located closer to the first polarizer 3, making compactness achievable.

As can be understood from what has been described, the present invention can provide a plane-of-polarization independent type of optical isolator that is of small size, of high resolution, and of low insertion loss, or, in other words, high performance. The present invention may also be applied to an optical circulator.

Claims

1. An optical isolator made up of a first polarizer for separating an incident light beam into two light beams that are perpendicular to each other in the polarization direction and are not parallel with each other in the propagation direction, a 45 degree Faraday rotator, a second polarizer that is identical with the first polarizer in terms of the light beam-separation angle but is different by 45 degrees from the first polarizer in terms of the angle the separated two light beams make to the polarization of the beams, and at least one birefringent crystal plane plate that has a function capable of converging two parallel light beams, with the planes of polarization at right angles with each other, into a single beam.

2. An in-line type of optical isolator equipment which, in addition to the isolator according to Claim 1, includes a lens for guiding the light leaving the optical fiber to a photometric optical fiber through its entrance.

3. An optical isolator according to Claim 1 or 2, wherein the first and second polarizers are Wollaston or Rochon prisms.

4. An optical isolator substantially as hereinbefore described and as illustrated in the accompanying drawings.

P~tents Act 1977
E~amin r's r port to the C mptroller under Section 17 (Th S arch Rep rt)

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Rel vant Technical fi lds

(i) UK Cl (Edition L) G2F (FCM)

(ii) Int Cl (Edition 5) G02F 1/09, 1/095

Search Examiner

G M PITCHMAN

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, CLAIMS, JAPIO

Date of Search

5 MAY 1993

Documents considered relevant following a search in respect of claims 1 TO 4

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	EP 0492437 A1 (SUMITOMO) - see Figure 2	1-4
A	EP 0415444 A2 (SEIKO) - see column 3 lines 6 to 13	1-4

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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